STATUS OF FORAGE PLANT REGENERATION IN GIR PROTECTED AREA

A Rapid Reconnaissance

Dr. AJT Johnsingh
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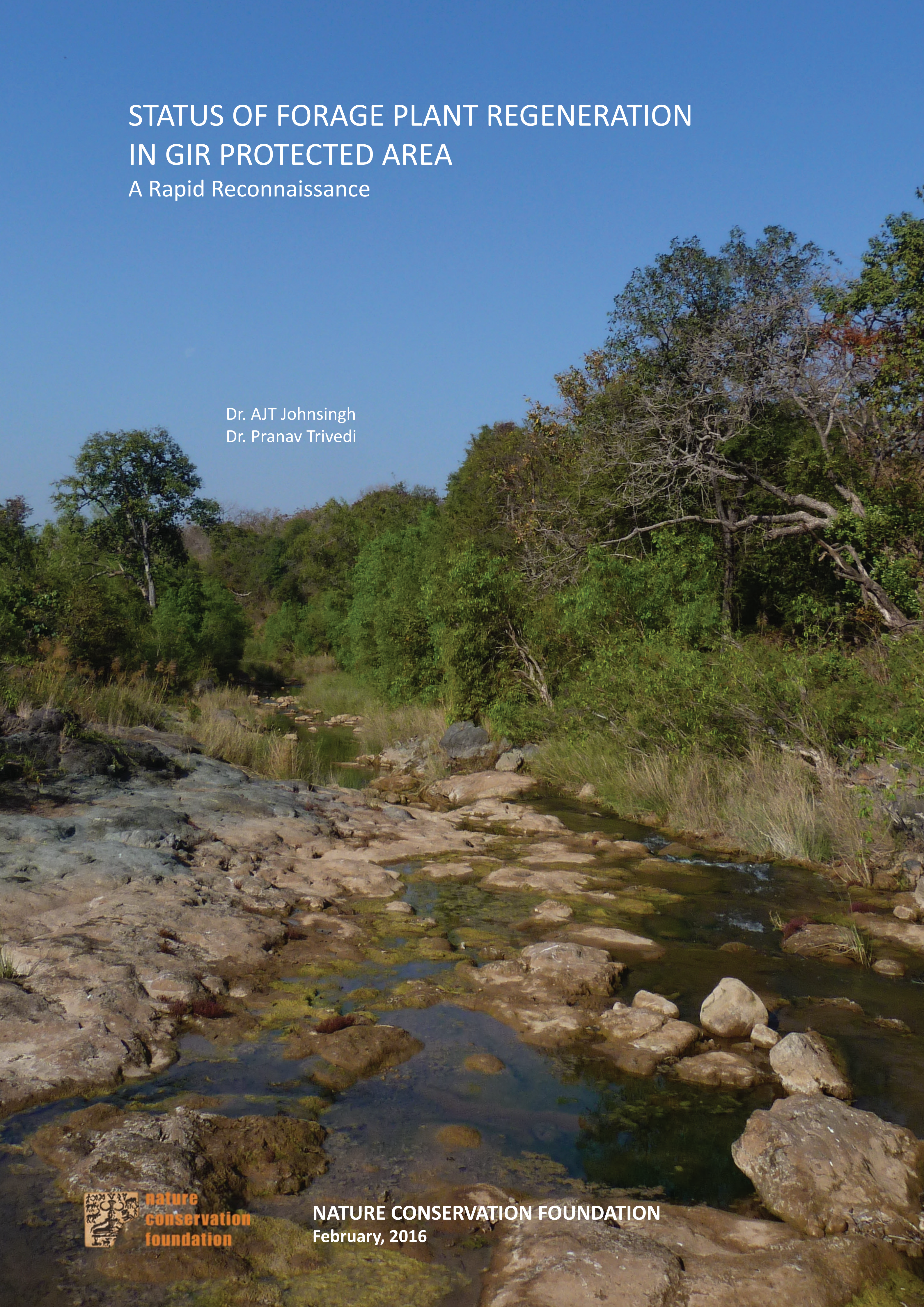

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NATURE CONSERVATION FOUNDATION
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CONTENTS

Summary **1**

Acknowledgements **3**

Introduction **4**

Study Site and Methods **5**

Results and Discussion **7**

- General trends of richness and abundance of plants
- Occurrence, abundance and regeneration status of forage plants
- Factors influencing regeneration
- Limitations of the present study
- Recommendations for management

References **15**

Colour Plates **17**

Appendices **27**

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SUMMARY

Introduction: We undertook a rapid reconnaissance of Gir National Park and Sanctuary (henceforth called Gir PA) - the last stronghold of the Asiatic Lion (*Panthera leo persica*) to assess the regeneration status of perennial forage plants (trees, shrubs and climbers) of wild ungulate species. The survey conducted from 6th to 11th February, 2015 was aimed at collecting preliminary information to aid in better management of the habitat.

Methods: We drove through most parts of the Gir PA (including Gir West and Gir East; Sanctuary & National Park) traversing about 436 km of roads passing through varied terrain and major vegetation types. Vegetation was surveyed along this route in 60 plots admeasuring 50 m x 10 m each. Of the 60 plots, 38 (63 %) were in Sanctuary area and 22 plots (37 %) were in the National Park. All trees, shrubs and perennial climbers were enumerated in each plot. All plants of less than 1 metre height were considered in recruitment stage and all those above this height were regarded as 'established' individuals.

Results & Discussion: We encountered 80 species of perennial flowering plants, which included 58 species of trees, 13 species of shrubs, eight species of perennial climbers and a bamboo. Median number of species per plot was 15.5 (Range=4 to 29). Only 12 out of 80 species (15 %) were encountered in 30 or more (≥ 50 %) plots. Of these, eight species viz. *Tectona grandis*, *Zizyphus mauritiana*, *Bauhinia racemosa*, *Acacia catechu*, *Grewia tiliaefolia*, *Randia dumetorum*, *Zizyphus oenoplia* and *Wrightia tinctoria* occurred in 35 or more plots. *Helicteris isora*, *Cassia fistula* and *Acacia leucophloea* occurred in 34 plots each, while *Diospyros melanoxylon* was found in 30 plots. These can be considered widespread or common species. Forty seven (47) species were found in 6 or less plots (≤ 10 %), with 12 species found only in one plot each. These 47 species were thus relatively rare. Ten species occurred in 7 to 12 plots (10 to 20 %), while 11 species were found in 13 to 29 plots (20 to 50 %); these were considered uncommon and frequent species respectively.

In all, 7,001 individual plants were enumerated in 60 plots, which included 4,206 (60 %) established plants (> 1 m height) and 2,795 (40 %) juveniles or recruiting individuals (< 1 m height). The median number of plants per plot was 104.5 (Range=10 to 334). Only 15 species contributed about 75 % of plants to the overall number (Appendix 1). The most abundant species among trees was Teak (*T. grandis*) and among shrubs *Antedi* (*H. isora*) with relative abundances of 15.6 % and 17.3 % respectively. The top five most abundant species were – *H. isora, T. grandis, W. tinctoria* (6.08 %), *Z. mauritiana* (4.96 %) and *R. dumetorum* (4.51 %) followed by *Holarrhena antidysenterica* (3.99 %), *D. melanoxylon* (3.56 %), *G. tiliaefolia* (3.36 %) and *C. fistula* (3.27 %). Number of species per plot and number of individuals per plot showed a statistically significant positive correlation

(r=0.714, df=58, p<0.0005, one-tailed test) indicating that a high number of species could potentially result in an increase in the number of plants.

Seventeen (17) species (68 %) out of the 25 important forage species showed poor regeneration. Only four species showed what could be termed good juvenile to established ratio, while four other species had fair regeneration. For some of the important forage species such as *A. catechu*, *Anogeissus latifolia*, *Xeromphis uliginosa* and *Z. xylopyrus*, the juvenile to established ratio was nil or close to that. It was clear that all species of *Acacia* and *Zizyphus* barring *A. leucophloea* and *Z. nummularia* had poor regeneration in the plots that we surveyed. This is a matter of concern for habitat management, ungulate prey and ultimately for the long-term conservation of Asiatic Lion.

Number of established individuals vis-à-vis the number of regenerating individuals for the 80 plant species encountered showed a highly positive correlation that was highly statistically significant (r=0.82, df=78, p<0.0005, one-tailed test). Even for the subset of 25 forage species included in Table 4, this correlation held true (r=0.77, df=23, p<0.0005, one-tailed test). This meant that high abundance of established adult plants was one of the major factors governing regeneration. However, this was not true for important forage species such as *Z. mauritiana*, *A. catechu* and *W. tinctoria*; which despite having a high number of established individuals showed very poor recruitment.

Major factors contributing to better survival and recruitment of forage plants that have been discussed in detail in the report include abundance of mature (mother) trees, availabiility of light vis-a-vis denseness of habitat (canopy density), influence of the herbivore community – especially the wild and domestic ungulates through direct removal and damage/trampling, dry season fire and its impacts, alien and invasive species impacts and indirect influence of large predators on vegetation through their prey preferences (top-down effects). Recommendations for research and monitoring and in terms of management interventions have been given to help in strengthening the improvement of Gir habitat.

ACKNOWLEDGEMENTS

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INTRODUCTION

Vegetation has a direct bearing on wildlife conservation and management as a primary producer of organic matter on which all organisms depend, directly or indirectly (Meena and Kumar 2012). It is also of dynamic nature due to succession, consumption by herbivores and environmental factors such as fire, cyclones, droughts (Meena and Kumar 2012) and anthropogenic influences including livestock grazing, collection of fuel, fodder and non-wood produces. Hence, its monitoring is of utmost importance in Protected Areas (PAs). An often overlooked aspect in monitoring and surveys is regeneration/recruitment of forage plants of major prey species i.e. ungulates. Regeneration in many Indian forests is inadequate to maintain balanced (plant) populations (Sukumar *et al*. 1992). This could hamper forage availability to the ungulate, which in turn would impact the population of apex predators in the long run. So far, very few intensive or detailed studies have been carried out in this regard.

Gir National Park and Sanctuary (henceforth called Gir PA) is the last stronghold of the Asiatic Lion (*Panthera leo persica*) in the world. Since the future of lion depends on the health of the Gir ecosystem, monitoring and periodic surveys of the habitat (vegetation) are necessary for better management of Gir PA. Hence, we undertook a rapid reconnaissance of Gir PA to assess the regeneration status of forage plants of major ungulate species from 6th to 11th February, 2015. The survey was aimed at collecting preliminary information on the status of forage plant (trees & shrubs) regeneration. The information generated is hoped to provide a coarse baseline for future studies and monitoring of more intensive and long-term nature. This, in turn will aid in better management of the habitat of Gir PA and ensure a secure future for the Asiatic Lion in Gujarat and India.

Aim: To carry out a rapid reconnaissance of the regeneration status of forage plants (trees & shrubs) of ungulates in Gir PA.

Objectives:

1. Qualitative and quantitative survey of forage plant species availability in Gir PA through rapid sampling using large plots.
2. Assess the regeneration of above species to guide future studies and monitoring.

STUDY SITE AND METHODS

Gir Protected Area: Gir PA is the last stronghold of the Asiatic Lion (*P. l. persica*). Located in the semi-arid Saurashtra peninsula of Gujarat State and covering 1412 km^2, it is clothed by dry deciduous teak and mixed forests, riparian forests, thorn forests and scrub-savanna vegetation. The PA harbours more than 3,000 species of plants and animals which include nearly 600 species of flowering plants. Detailed description of the PA and its major features is available through many sources (e.g. Dave 2008, Meena and Kumar 2012).

Methods: We drove through most parts of the Gir PA (including Gir West and Gir East; Sanctuary & National Park) in a four-wheeler starting from the head-quarters at Sasan Gir to Rajasthali *ness* in East Gir and back to Sasan Gir from 6th to 11th February, 2015 traversing about 436 km of roads using a circuitous route and passing through varied terrain (see Table 1 for detailed itinerary). Vegetation was surveyed along this route in 60 plots admeasuring 50 m x 10 m each. Of the 60 plots, 38 (63 %) were in Sanctuary area and 22 plots (37 %) were in the National Park (details in Table 2).

Table 1. Route for survey of forage plant regeneration in Gir PA

Date	Itinerary for Survey
6th February, 2015	Sasan-Raidi-Dedakdi-Dudhala-Kerambha-Sasan
7th February, 2015	Sasan-Ambla Hill-Kamleshwar-Varvangda-Nima-Patariyala-Kankai-Lilapani barrier-Kankai-Chhodavdi
8th February, 2015	Chhodavdi-Banej Charchok-Lapatni-Bhimchas-Tulsishyam-Jasadhar-Rajasthali-Jasadhar
9th February, 2015	Jasadhar-Bhimchas- Aral-Lapatni-Banej Charchok-Dabhala-Jamwala-Shingavda dam-Jamwala
10th February, 2015	Jamwala-Batheshwar-Mundachowk-Janwadla-Gola-Janwadla
11th February, 2015	Janwadla-Deva dungar-Sirwan-Kapuriya-Sasan-Ratanghoona-Kadeli-Sasan

Plots were randomly laid on both sides of the road leaving the immediate vicinity (c. 15-20 m), where fireline work is carried out. Efforts were made to include as many vegetation types as possible in the sampling. All trees, shrubs and perennial climbers were enumerated in each plot. All plants of less than 1 m height were considered in recruitment stage and all those above this height were regarded as 'established' individuals. Thorough and systematic search was made to detect smallest of the seedlings/saplings in each plot (also within tall grass) by two individuals. Plant identification was carried out with the help of an experienced local field assistant as well as our own knowledge and experience.

Table 2. Sampling effort for reconnaissance of forage plant regeneration in Gir PA

Day	Distance (km)	No. of Plots		
		WLS	NP	Total
1	40	5	0	5
2	84	8	3	11
3	102	6	4	10
4	98	6	5	11
5	70	4	9	13
6	42	9	1	10
Total	**436**	**38**	**22**	**60**

Information on forage plants of major ungulates (i.e. chital, sambar and nilgai) was obtained from previous research conducted in Gir PA (Khan 1994, Dave 2008) as well as based on senior investigator's experience. Along the route, we also took notes and photographs. The regeneration status of a species was considered:

- "good" when number of <1 m individuals was >> number of >1 m individuals
- "fair" when number of <1 m individuals was > number of >1m individuals and
- "poor" when the number of <1 m individuals was < number of >1 m individuals.

MS Excel was used for all data entry, plotting of graphs and analyses.

RESULTS & DISCUSSION

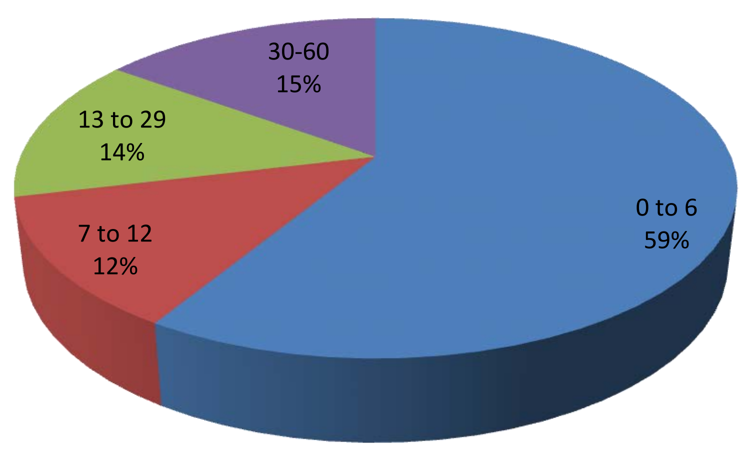
General trends of richness and abundance: We encountered 80 species of perennial flowering plants (trees, shrubs, climbers & bamboo), which included 58 species of trees, 13 species of shrubs, eight species of perennial climbers and a bamboo (Appendix 1).

Table 3. Salient features of results

Feature	Numbers
Minimum number of species / Plot	4
Maximum number of species / Plot	29
Median number of species / Plot	15.50
Average number of species / Plot	15.28
Minimum number of plants / Plot	10
Maximum number of plants / Plot	334
Median number of plants / Plot	104.5
Mean number of plants / Plot	116.7
Number of Established Plants (>1 m)	4206
Number of Regenerating Plants (<1 m)	2795
Total number of plants	**7001**

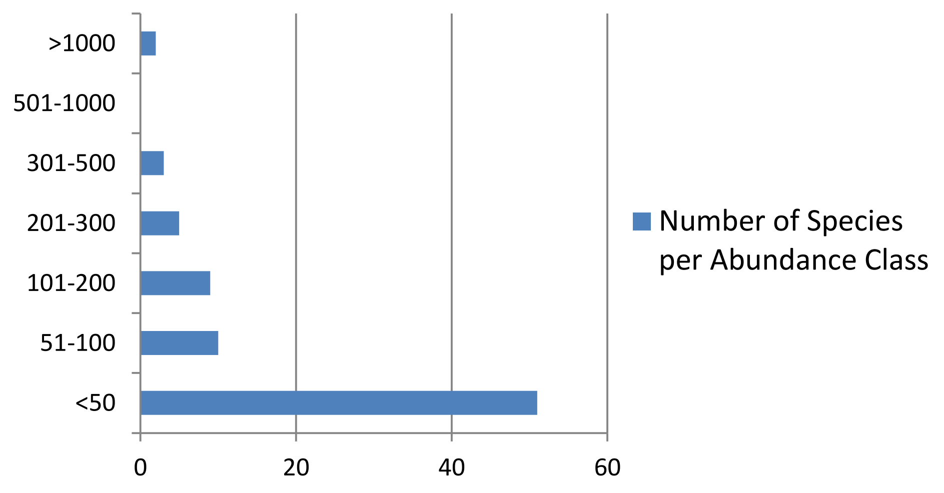
Median number of species per plot was 15.5 (Range=4 to 29). All except one species could not be identified as the plant was a leafless seedling. Only 12 out of 80 species (15 %) were encountered in 30 or more (≥ 50 %) plots (Figure 1).

Figure 1. Percentage of Species per Plot Number



Of these, eight species viz. *T. grandis*, *Z. mauritiana*, *B. racemosa*, *A. catechu*, *G. tiliaefolia*, *R. dumetorum*, *Z. oenoplia* and *W. tinctoria* occurred in 35 or more plots. *H. isora*, *C. fistula* and *A. leucophloea* occurred in 34 plots each, while *D. melanoxylon* was found in 30 plots. These can be considered widespread or common species. Forty seven (47) species were found in 6 or less plots (≤ 10 %), with 12 species found only in one plot each. These 47 species were thus relatively rare. Ten species occurred in 7 to 12 plots (10 to 20 %), while 11 species were found in 13 to 29 plots (20 to 50 %); these were considered uncommon and frequent species respectively.

Figure 2. Number of Species per Abundance Class



In all, 7,001 individual plants were enumerated in 60 plots, which included 4,206 (60 %) established plants (> 1 m height) and 2,795 (40 %) juveniles or recruiting individuals (< 1 m height). The median number of plants per plot was 104.5 (Range=10 to 334). Only 15 species contributed about 75 % of plants to the overall number (Appendix 1). The most abundant species among trees was Teak (*T. grandis*) and among shrubs *Antedi* (*H. isora*) with relative abundances of 15.6 % and 17.3 % respectively. The top five most abundant species were – *H. isora, T. grandis, W. tinctoria* (6.08 %), *Z. mauritiana* (4.96 %) and *R. dumetorum* (4.51 %) followed by *H. antidysenterica* (3.99 %), *D. melanoxylon* (3.56 %), *G. tiliaefolia* (3.36 %) and *C. fistula* (3.27 %). Number of species per plot and number of individuals per plot showed a statistically significant positive correlation (r=0.714, df=58, p<0.0005, one-tailed test) indicating that a high number of species could potentially result in an increase in the number of plants.

Occurrence, abundance and regeneration status of forage plants: Khan (1994) and Dave (2008) both listed 38 species of plants (excluding herbs and grasses) in the diet of chital. Out of these, three species of *Acacia* and *Zizyphus* each dominated the spectrum. Leaves and pods of *Acacia* sp. and leaves/fruits of two species of *Zizyphus* formed nearly 45 % of chital diet by dry biomass (Dave 2008) in East Gir. Khan (1994) recorded a high frequency (41 to 50 %) of foraging on *Acacia*s and *Zizyphus* sp. by chital. Khan (1994) also documented food plants of sambar (*Rusa unicolor*) and nilgai (*Boselaphus tragocamelus*) - the other two ungulates known to be major prey species of the lion at Gir. These two utilised 28 and 19 species of plants (excluding herbs and grasses) respectively. It is likely that higher number of species were recorded for chital as it is more gregarious and frequents open woodland and savanna vegetation. We used the above information and short-listed 25 important forage plant species (parts eaten: leaves, shoots, fruits/pods and bark) used as forage by the three major ungulate species of Gir PA (Table 4).

Table 4. Key forage plant species of ungulates and their regeneration in Gir

No.	Species	Number of Established Individuals	Number of Juveniles	Juvenile/ Established Ratio
1	*A. catechu*	98	10	0.10
2	*A. leucophloea*	54	42	0.78
3	*A. nilotica*	72	29	0.40
4	*Anogeissus latifolia*	52	2	0.04
5	*Balanites aegyptica*	27	46	1.70
6	*Bauhinia racemosa*	110	47	0.43
7	*Butea monosperma*	70	31	0.44
8	*Capparis sepiaria*	53	110	2.08
9	*Carissa congesta*	94	57	0.61
10	*Cassia fistula*	38	191	5.03
11	*Dichrostachys cineria*	41	11	0.27
12	*Diospyros melanoxylon*	91	158	1.74
13	*Flacourtia indica*	16	56	3.50
14	*Grewia tiliaefolia*	128	107	0.84
15	*Helicteris isora*	715	495	0.69
16	*Phyllanthes emblica*	33	7	0.21
17	*Randia dumetorum*	117	199	1.70
18	*Terminalia bellirica*	6	7	1.17
19	*Terminalia tomentosa*	64	31	0.48
20	*Wrightia tinctoria*	328	98	0.30
21	*Xeromphis uliginosa*	5	0	0.00
22	*Zizyphus mauritiana*	312	35	0.11
23	*Z. nummularia*	23	52	2.26
24	*Z. oenoplia*	103	45	0.44
25	*Z. xylopyrus*	24	0	0.00

Appendix 1 shows the total number, numbers of established and juvenile plants and juvenile to established ratio of all the 80 species encountered during our survey. Overall ratio of juveniles to established plants was 0.66, which was on the lower side. Our reconnaissance showed that 17 species (68 %) out of the 25 depicted in Table 4 showed “poor” regeneration. Only four species showed what could be termed “good” juvenile to established ratio (shown in green in Table 4), while four others had a ratio of between 1 and 2 that could be termed “fair” (in blue). For some of the important forage species such as *A. catechu*, *A. latifolia*, *X. uliginosa* and *Z. xylopyrus*, the juvenile to established ratio was “nil” or close to that and hence under “poor” category (Table 4). It was clear that all species of *Acacia* and *Zizyphus* barring *Z. nummularia* (Table 4) showed “poor” regeneration. This is a matter of concern for habitat management and for future course of action at Gir PA.

Number of established individuals vis-à-vis the number of regenerating individuals for the 80 plant species encountered showed a highly positive correlation that was statistically significant (r=0.82, df=78, p<0.0005, one-tailed test). Even for the subset of 25 forage species included in Table 4, this correlation held true (r=0.77, df=23, p<0.0005, one-tailed test). This meant that high abundance of established (adult) plants was one of the major influences on regeneration. However, a closer look at the juvenile/established ratios marked ‘in red’ shows that some species despite having a high number of established individuals did not show high recruitment. *Z. mauritiana, W. tinctoria* and *A. catechu* were examples of such species.

Factors influencing regeneration: In general, most mature trees would produce several hundred or thousand seeds, of which few will germinate and turn into seedlings. These will be subjected to high mortality due to various environmental factors before reaching sapling stage. Once the saplings reach a certain size (which may vary from species to species – here we took it as more than 1 m height), they are less vulnerable to grazing, fire, trampling and other causes of mortality including moisture stress (see Grubb in Edwards *et al*. 1996). Estimates of replacement ratios from seedling to sapling to mature trees (even at a coarse level) are not available for most forage species found in Gir PA.

It is known that amount and quality of light available to the regenerating plants (seedlings/saplings) vis-à-vis their life history traits is a major determinant of their survival and establishment as adult individuals. Canopy density is an essential parameter to assess and analyse the factors affecting forest growth, its regeneration and to keep a check on management initiatives in areas of plantations and regeneration status (Chauhan 2004). Meena and Kumar (2012) and Alam *et al*. (2014) opined that in Gir PA (particularly Gir West), habitat protection measures have led to improved canopy cover making the habitat dense and less conducive for light-demanding species that have good browse value. This hypothesis is worth testing systematically. Our observations suggest that opener areas did not necessarily have better regeneration, nor did dense canopy of riverine forest curtail good regeneration. We reckon that a multitude of important factors that include abundance of adult/mature plants, browsing/grazing intensity, trampling and management regime (National Park or Sanctuary) and fire history also seem to influence regeneration of forage plants.

In general, tall grass areas seemed to favour good regeneration as grass allowed for light availability, while providing cover and preventing easy detection by grazing animals. Jensen *et al*. (2012) also noted that although shrubs restricted oak seedling growth in Swedish forests, they initially facilitated oak regeneration by concealment, and subsequently by numeric dilution. Tall, dense grass too could assume this role. However, it would also be hazardous due to possibility of fire during the dry season. Also, our observations were limited to the plots and their surrounding areas, so it is not advisable to generalize this observation at this stage.

Other obstacles preventing good natural regeneration of vegetation in Gir PA entail the spread of alien, invasive species such as Lantana (*Lantana camara*), 'Gando Bawal' (*Prosopis juliflora*) and 'Kuwadiyo' (*Cassia tora*). Lantana's spread by 2011-12 was reportedly 150 km^2 (Meena and Kumar 2012). This is over one tenth the area of Gir PA and needs to be checked. *C. tora* is not such a major issue at present as it is an annual, but *P. juliflora* though restricted to the peripheral areas of Gir PA, is known to be a big danger to natural flora and can overpower the native plant species in a short period. Many alien, invasive species possess allelopathic properties and actively prevent other species from growing nearby.

Ungulate browsing is one of the many factors that affect tree establishment, growth and mortality and thus both structure and species composition of forests (Swiss Federal Institute for Forest, Snow and Landscape Research WSL 2015). Ungulates are known to have high impacts on plant community structure and composition across all vegetation types in tropical and temperate realms by consuming leaves, twigs, stems, flowers, seeds and fruits, as well as regeneration (Augustine and McNaughton 1998, Weisburg and Bugmann 2003, Jayakumar and Nair 2013, Swiss Federal Institute for Forest, Snow and Landscape Research WSL 2015). Because browsing is selective, it also leads to a reduction or even annihilation of preferred plant species The herbivores exert an influence mainly through reduction in abundance of palatable species (due to damage to plant tissues and no/low recovery) and a concomitant increase in the abundance of unpalatable species; or the exactly reverse effect i.e. keeping a check on unpalatable species and increasing the abundance of palatable species (Review in Augustine and McNaughton 1998). Though various factors are described in Swiss Federal Institute for Forest, Snow and Landscape Research WSL (2015), Augustine and McNaughton (1998) conclude that only two major aspects – forage selection by ungulates and plant tolerance/response to herbivory are of consequence and need to be looked at relative scales.

At Gir PA, browsing and damage/trampling by nearly 1,00,000 (0.1 million) wild and domestic herbivores (buffalo, cattle, chital, sambar, chinkara, chousingha, nilgai, wild pig, common langur and Indian porcupine) and are sure to influence the structure and composition of vegetation. High ungulate abundance could lead to shifts in plant species composition and problems for forest regeneration (Weisburg and Bugmann, 2003).

Newton (1989) followed one group of common langur (*Semnopithecus entellus*) in Kanha in sal dominated area and the group dropped 1500 kg food in a year which was used by chital mainly in summer and winter. It gives an idea about the impact of an arboreal herbivore on vegetation.

The community of wild carnivores at Gir includes nearly 1,000 big cats (lion and leopard). Their influence on ungulates and subsequent impact on vegetation is not well understood. Banerjee *et al*. (2013) showed that there was evidence of selective utilization of prey by lions and predation was skewed towards large, wild ungulate prey species. Chital, sambar, nilgai and wild pig were found to be utilized more than their availability, while buffaloes were used less and cattle in proportion to their availability respectively (Banerjee *et al*. 2013). The order of prey preference by lions was sambar, wild pig, nilgai, chital and cattle and percentage biomass contribution of different prey species to the lions' diet was most for livestock (33.7%) followed by chital (28.9%) and 28.3% for sambar (Banerjee *et al*. 2013). We suspect there is strong predation pressure on the relatively small population of sambar as well as wild pig and nilgai, more so with high densities of lions within Gir PA. This could lead to a reduction in the abundance of wild prey such as sambar, nilgai and wild pig, while chital numbers which have soared (Khan *et al*. 1996) over the last two to three decades will not be influenced to that extent. During the survey, we traversed 436 km of roads and encountered 849 chital, but only 15 sambar, 24 wild pig and 10 nilgai.

The high density of chital and their preference for leaves and fruits/pods of *Z. mauritiana* and *Acacia* sp. could have an impact on population structure of these plant species through hampered regeneration. Besides, chital being one of the smaller ungulates would influence (and probably deplete) the lower layers of vegetation. Prins & Van der Jeugd (1993) suggested that dramatic reduction of impala numbers (*Aepyceros melampus*) following outbreaks of rinderpest and anthrax enhanced seedling recruitment of *Acacia tortilis*. They also showed that when browsing pressure by impala was high, *Acacia* seedling establishment was rare. The impact of impala and other medium-sized herbivores reduced with tree maturation as most foliage of a mature tree grows beyond reach of these herbivores (Prins & Van der Jeugd 1993). It is relevant to point out that impala and chital are similar-sized ungulates (average height at shoulder c. 90 cm), so a similar impact in Gir PA cannot be ruled out. Also, as noted in the Bialowieza Forest in Poland, presence of wolf (*Canis lupus*) creates 'pockets of fear' and suspicion where low presence of deer leads to better regeneration of trees. In this case, the pockets included dead tree stumps and dense vegetation thickets, generally near wolf scat (quoted in Swiss Federal Institute for Forest, Snow and Landscape Research WSL 2015). This phenomenon is likely in case of leopard/lion scats and thickets/tall grass areas of Gir PA.

Dry season fires are common and damage or destroy regeneration, seeds lying on ground as well as mature trees across large tracts in Gir PA. Fireline creation helps reduce this risk, but does not eliminate it altogether. Maldharis residing in Gir cut/lop vegetation to feed their livestock, while people living in the peripheral villages illegally collect fuelwood and non-timber forest produce (NTFP). This also has a negative influence on regeneration through its impact on phenology and availability of seeds of forage plants. Rainfall could be a major limiting factor for plant regeneration, but for the past decade or so; rainfall has remained consistently good or above average.

Limitations of the present survey: This 6-day reconnaissance was undertaken only as a pilot survey using the extensive road network within Gir PA. Though we took care to space the successive plots by a reasonable distance and covered most habitat/vegetation types, it was not possible to survey interior forest areas and high hills due to time constraints. We classified and enumerated plants into only two categories viz. <1 m height and >1 m height and did not differentiate between seedling, sapling and other growth stages of plants. This caused some loss of information, but allowed for greater coverage of area within the given time frame.

Recommendations for management: These are divided into two sections concerning research-monitoring and direct management interventions as given below.

Research and Monitoring

- It is important to conduct studies to understand population structure of major plant species at Gir PA. Knowledge of age class composition of major tree species could be handy in management of the habitat including its manipulation for the benefit of the lion.
- Intensive behavioural studies on foraging of ungulates are needed to get better and reliable information (qualitative & quantitative) on food plants and parts eaten as well as
- Experimental plots of up to 10 ha to carry out controlled canopy-opening up and pollarding of coppicing forage species as per section 7.3.1 of the Management Plan for Gir PAs (Meena and Kumar 2012) would go a long way in documenting the vegetation parameters, especially regeneration and study the impacts of this manipulation as suggested in the plan.
- Pairs of fenced and unfenced plots (n = 20) of 40 x 40 m can be monitored for documenting and utilizing the impact of ungulates on plant regeneration.
- Areas of the National Park having tall grass and absence of grazing and of the Sanctuary with livestock grazing need to be compared with respect to survival and fate of seedlings/saplings.
- Vegetation monitoring suggested by the Wildlife Institute of India as part of the eco-development project (Qureshi and Shah, in Jhala 2004) need to be implemented.

Management Interventions

- Installing 5 to 10 large, mobile exclosures of 20 x 20 m or even 50 x 50 m around good, healthy specimens of important forage tree species such as *Z. mauritiana, A.*

nilotica, A. leucophloea, A. catechu and others to protect and enhance their regeneration could be tried in each range. Such exclosures would also help protect regeneration of non-target species. The exclosures can be moved to other trees after a span of two years.

- The good old system of having Preservation Plots to protect strong and healthy mother trees in rich forest tracts is essential for long-term health and management of habitat in Gir. Only good quality forest patches (especially in riverine & non-teak or teak-mixed forest) of 1 to 5 ha should be selected and fenced for this purpose.
- Intensive fire control and management regime needs to be strengthened and prevention of fire incidents needs to be given priority in habitat management.
- Livestock grazing, other than from *Maldhari* settlements needs to be prevented. We agree with Banerjee *et al*. (2013) that owing to a lion focused conservation objective of Gir and to avoid negative impacts of removal of vegetation and trampling, livestock numbers should be regulated or gradually reduced with rotational grazing practices being adopted for Maldhari livestock on an experimental basis for a period of 3-5 years.
- It is a good idea to allow people to cut and take away the tall grass for three weeks or so (if there is a demand) to reduce fire hazard. Some supervision and clear instructions about not removing regenerating plants would be useful.
- Natural regeneration needs to be augmented by planting 1 m tall saplings of major forage species. These should be prepared in nurseries in peripheral villages and planted with the help of local people.
- Removal of the two major alien, invasive species - *L. camara* and *P. juliflora* that suppress the regeneration of native plants should be accorded top priority for habitat improvement as echoed in recommendations (section 7.3.2) of the Management Plan of Meena and Kumar (2012). These should be properly implemented.

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Panoramic view of Gir Forest from Ambla Hill

Dry deciduous forest of teak-mixed type

Acacia-Zizyphus thorn woodland

Savanna and grassland habitat

Banyan (*Ficus benghalensis*) is an important species of the Gir Forest

A patch of dense riverine forest

Field work in progress for forage plant regeneration

Principal author and Field assistant engrossed in field work

Laying of plots and looking for small seedlings/saplings

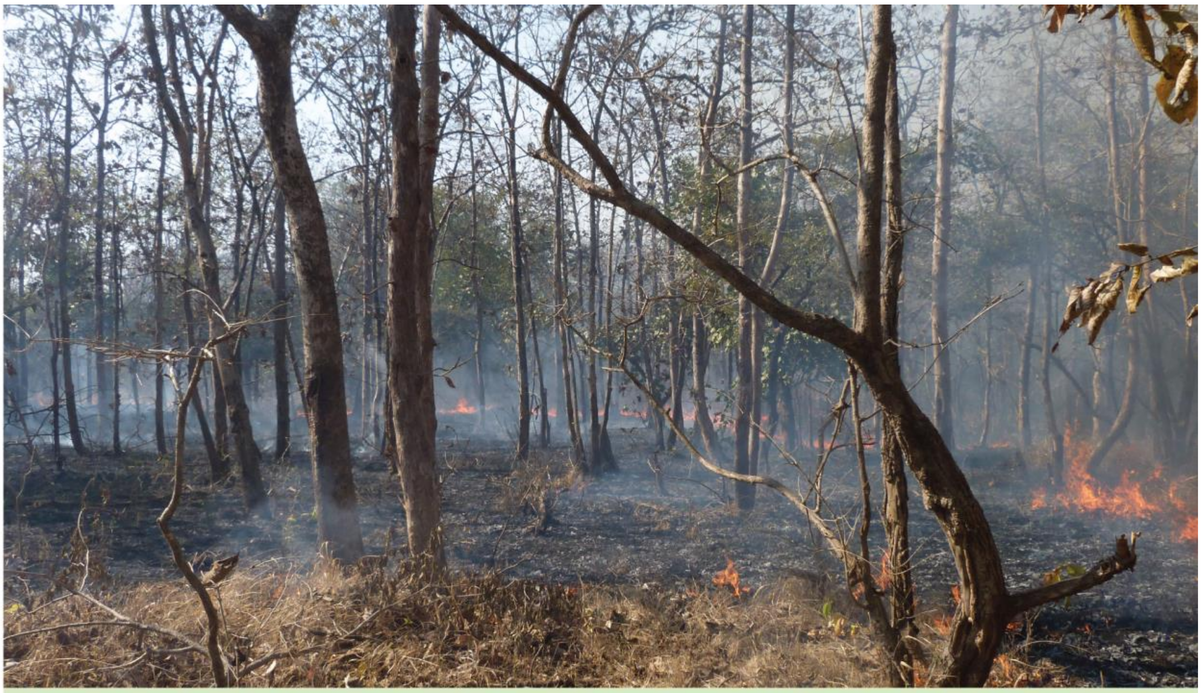
Chital - the most abundant ungulate prey species in Gir

Sambar - the largest deer of India seen feeding on *Flacourtia indica* leaves at Gir

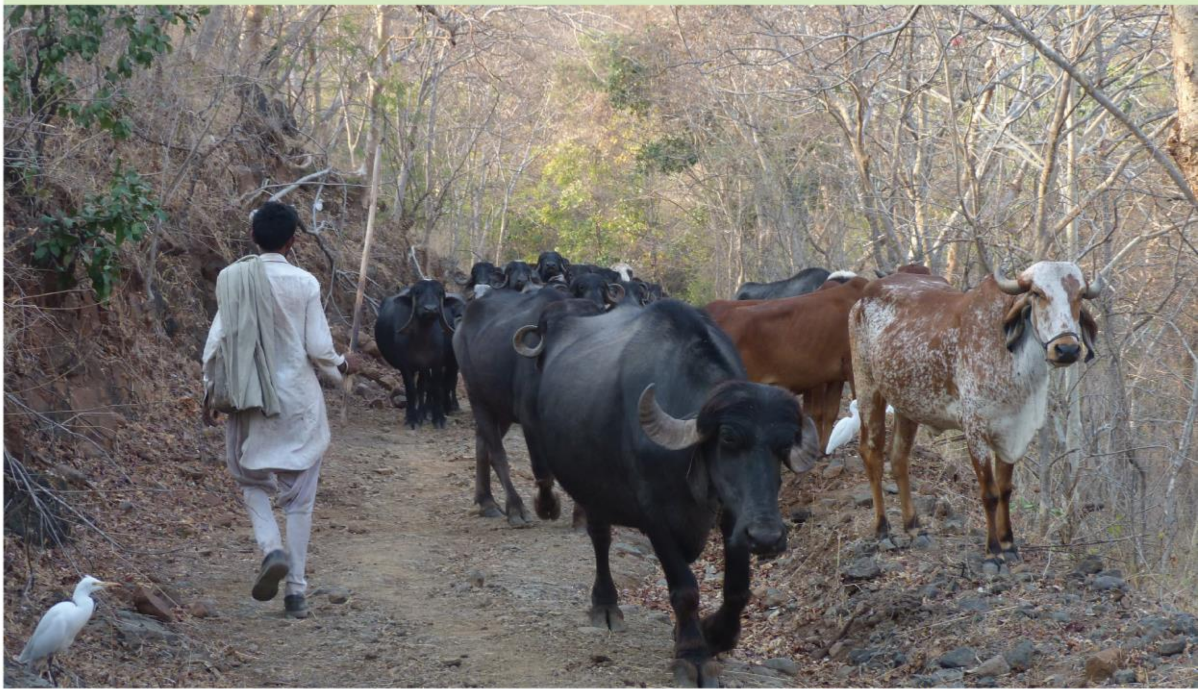
Nilgai - a herd-living antelope of the dry regions

Nilgai feeding on *Acacia leucophloea*

Important food items of ungulates in Gir



Fire and browsing-trampling by livestock influence the regeneration



APPENDIX 1. Plant Species Occurrence, Abundance and Regeneration at Gir PA (No. of Plots = 60)

Sr. No.	Species	Habit	Frequency of Occurrence	No. of Individuals >1	No. of Individuals <1	Proportion of <1 to >1	Total Individuals	Relative Abundance (%)
1.	*Acacia catechu*	T	38	98	10	0.10	108	1.54
2.	*Acacia ferruginea*	T	6	12	0	0.00	12	0.17
3.	*Acacia leucophloea*	T	34	54	42	0.78	96	1.37
4.	*Acacia nilotica*	T	25	72	29	0.40	101	1.44
5.	*Acacia senegal*	T	4	7	0	0.00	7	0.10
6.	*Adina cordifolia*	T	1	1	0	0.00	1	0.01
7.	*Aegle marmelos*	T	19	58	73	1.26	131	1.87
8.	*Alangium salvifolium*	T	8	61	29	0.48	90	1.29
9.	*Albizzia odoratissima*	T	6	6	0	0.00	6	0.09
10.	*Albizzia procera*	T	1	1	3	3.00	4	0.06
11.	*Anogeissus latifolia*	T	4	52	2	0.04	54	0.77
12.	*Asparagus sp.*	C	1	0	1	-	1	0.01
13.	*Azadirachta indica*	T	3	1	14	14.00	15	0.21
14.	*Balanites aegyptica*	T	9	27	46	1.70	73	1.04
15.	*Bauhinia sp.*	T	1	0	2	-	2	0.03
16.	*Bauhinia racemosa*	T	39	110	47	0.43	157	2.24
17.	*Bomabax ceiba*	T	6	14	0	0.00	14	0.20
18.	*Boswellia serrata*	T	3	5	0	0.00	5	0.07
19.	*Bridelia retusa*	T	1	1	0	0.00	1	0.01
20.	*Butea monosperma*	T	23	70	31	0.44	101	1.44
21.	*Capparis decidua*	S	22	53	110	2.08	163	2.33
22.	*Carissa congesta*	S *	23	94	57	0.61	151	2.16
23.	*Casearia elliptica*	T	1	2	0	0.00	2	0.03
24.	*Cassia fistula*	T	34	38	191	5.03	229	3.27

25.	*Cassia siamea*	T	1	0	28	-	28	0.40
26.	*Celastrus paniculata*	C	4	5	4	0.80	9	0.13
27.	*Cissus repandra*	C	3	4	0	0.00	4	0.06
28.	*Clerodendrum phlomidis*	S	3	14	0	0.00	14	0.20
29.	*Cocculus hirsutus*	C	8	8	16	2.00	24	0.34
30.	*Combretum ovalifolium*	C	5	10	2	0.20	12	0.17
31.	*Cordia myxa*	T	1	1	0	0.00	1	0.01
32.	*Crateva nurvala*	T	4	3	1	0.33	4	0.06
33.	*Dalbergia latifolia*	T	5	3	3	1.00	6	0.09
34.	*Dalbergia lanceolaria*	T	2	3	0	0.00	3	0.04
35.	*Dendrocalamus strictus*	B	3	83	0	0.00	83	1.19
36.	*Dichrostachys cinerea*	T	17	41	11	0.27	52	0.74
37.	*Diospyros melanoxylon*	T	30	91	158	1.74	249	3.56
38.	*Erythrina indica*	T	3	1	2	2.00	3	0.04
39.	*Ehretia laevis*	T	4	7	2	0.29	9	0.13
40.	*Ficus benghalensis*	T	2	22	0	0.00	22	0.31
41.	*Ficus religiosa*	T	3	2	1	0.50	3	0.04
42.	*Flacourtia indica*	T	21	16	56	3.50	72	1.03
43.	Gandhari Bordi (?)	S #	6	6	1	0.17	7	0.10
44.	*Garuga pinnata*	T	5	8	1	0.13	9	0.13
45.	*Grewia hirsuta*	S	2	1	11	11.00	12	0.17
46.	*Grewia tiliaefolia*	T	37	128	107	0.84	235	3.36
47.	*Helicteris isora*	S #	34	715	495	0.69	1210	17.28
48.	*Holarrhena antidysenterica*	S #	24	121	158	1.31	279	3.99
49.	*Holoptelia integrifolia*	T	5	7	7	1.00	14	0.20
50.	*Holostemma annulare*	C	2	3	2	0.67	5	0.07
51.	*Ixora arborea*	S *	1	0	1	-	1	0.01
52.	*Kydia calycina*	T	3	10	0	0.00	10	0.14
53.	*Lannea coromandelica*	T	9	23	3	0.13	26	0.37

54.	*Lantana camara*	S	10	107	98	0.92	205	2.93
55.	*Leptadenia reticulata*	C	2	4	0	0.00	4	0.06
56.	*Miliusa tomentosa*	T	16	41	32	0.78	73	1.04
57.	*Mitragyna parviflora*	T	8	15	104	6.93	119	1.70
58.	*Morinda tinctoria*	T	7	5	2	0.40	7	0.10
59.	*Phyllanthes emblica*	T	17	33	7	0.21	40	0.57
60.	*Pongamia pinnata*	T	1	0	1	-	1	0.01
61.	*Pterocarpus marsupium*	T	2	1	1	1.00	2	0.03
62.	*Randia dumetorum*	T	36	117	199	1.70	316	4.51
63.	*Rhynchosia sp.*	C	4	5	0	0.00	5	0.07
64.	*Sapindus emarginatus*	T	6	1	10	10.00	11	0.16
65.	*Schleichera oleosa*	T	4	1	4	4.00	5	0.07
66.	*Schrebera swieteniodes*	T	4	14	0	0.00	14	0.20
67.	*Securinega leucopyrus*	S	5	22	2	0.09	24	0.34
68.	*Soymida febrifuga*	T	10	11	6	0.55	17	0.24
69.	*Sterculia urens*	T	3	3	0	0.00	3	0.04
70.	*Syzygium sp.*	T	1	0	1	-	1	0.01
71.	*Tectona grandis*	T	50	788	302	0.38	1090	15.57
72.	*Terminalia bellirica*	T	8	6	7	1.17	13	0.19
73.	*Terminalia tomentosa*	T	25	64	31	0.48	95	1.36
74.	Unknown *sp.*	S	1	0	1	-	1	0.01
75.	*Wrightia tinctoria*	T	35	328	98	0.30	426	6.08
76.	*Xeromphis uliginosa*	T	4	5	0	0.00	5	0.07
77.	*Zizyphus mauritiana*	T	49	312	35	0.11	347	4.96
78.	*Zizyphus nummularia*	S	5	23	52	2.26	75	1.07
79.	*Zizyphus oenoplia*	S *	36	103	45	0.44	148	2.11
80.	*Zizyphus xylopyrus*	T	9	24	0	0.00	24	0.34
	TOTALS			**4206**	**2795**	**0.66**	**7001**	**100.00**

B=Bamboo, C=Climber, S=Shrub, T=Tree , (?) Scientific name not known, * Shrub - straggler, # Typically a shrub, can grow into a tree

Appendix 2. Observations and Comments on Some Important Food Plants of Wildlife (with special reference to Gir PA)

1. ***Acacia nilotica***: Eaten by chital. Saw fruits being dropped by parakeet. Fruits should be very nutritious. Same may be applicable to *A. leucophloea, A. catechu* too but forage provided could be less.
2. ***Aegle marmelos***: Fruits important in dry season. Good regeneration seen at Gir.
3. ***Anogeissus latifolia***: Should be a good fodder as the *Gujjars* in Rajaji NP lop them right and left. Fallen leaves are plenty which should be eaten by ungulates. In Ranthambhore TR, fallen leaves of *A. pendula* are eaten by sambar and in the periphery by the cattle.
4. ***Balanites aegyptica***: East African species. Fruits fondly eaten by ungulates and the seeds later regurgitated. Saw good regeneration in fire prone areas also in Gir.
5. ***Bauhinia racemosa***: Leaves and young pods (fruits) extremely palatable. Fruits should be nutritious also.
6. ***Boswellia serrata***: Have seen sambar feeding on the young leaves. Mature leaves can be very aromatic. In Moyar Gorge - Mudumalai TR, elephants feed on the bark by debarking it with their tusks, gradually resin comes out. When the the resin catches fire, the fire gets into the core of the trunk resulting in the death of the tree.
7. ***Bridelia retusa***: Birds feed on the fruits. Ungulates should be eating the fruits. One species elephants can't kill by debarking as the bark grows back unlike sal and teak.
8. ***Butea monosperma***: Fallen flowers which are succulent eaten by the ungulates. Flowering coincides with the onset of the dry season, so it is a key resource. Flowers and pods also attract birds.
9. ***Bombax ceiba***: Same is applicable to *Bombax ceiba*. The amount of flowers *B. ceiba* produces in productive habitats like terai is amazing. The species need propagation.
10. ***Capparis decidua***: In spite of the powerful hooked thorns, leaves are eaten by ungulates particularly by nilgai and sambar, and also chital. Important forage species and showed good regeneration in Gir.
11. ***Carissa congesta***: Ungulates should be feeding on the fruit - difficult to observe as it is a shrub-straggler. Provides excellent shade to wildlife – lion, Indian peafowl, chital use it extensively to rest in Gir.
12. ***Cordia myxa***: In Rajaji NP saw peafowl up in the tree feeding on the fruits; fallen fruits should be eaten by the ungulates. Not rgenerating well at Gir.
13. ***Crateva nirvala***: Fruits red and attractive - birds eat them. Occurs scantily and shows poor regenration at Gir.
14. ***Dendrocalamus strictus***: All ungulates feed on the leaves of this bamboo. This is one species that Forest Department could propagate.

15. ***Dichrostachys cinerea***: Young leaves eaten by langur, chital, nilgai and sambar. But the availability is less and regeneration is poor.
16. ***Diospyros melanoxylon***: Saw nilgai feeding on the fruits in Ranthambhore TR. Good regeneration at Gir.
17. ***Ehretia laevis***: Elephants feed on the bark, birds on the fruits.
18. ***Ficus bengalensis* and *F. religiosa***: Highly important and key species for a variety of wildlife; also important as resting and roosting habitat for lion, leopard, peafowl, chital and langur.
19. ***Flacourtia indica***: We saw a sambar stag feeding on it in East Gir. All ungulates feed on this shrub/tree. Regeneration is good at Gir.
20. ***Garuga pinnata***: Exceedingly important forage tree. Uncommon in Gir (called *Karapti* in local). Fruits are eaten by all ungulates. In Nagarahole TR, it seems the Coorgi poachers hide and wait near a fruiting tree to shoot barking deer. Gir should care for the species promoting its regeneration and abundance.
21. ***Grewia hirsuta***: Leaves are eaten by the ungulates. Fruits are edible to humans as well as to sloth bear.
22. ***Grewia tilaefolia***: Leaves are fondly eaten by ungulates. Regeneration should be a problem. Management should take care of the species. In Bandipur saw a barking deer feeding on a dry fallen leaf, ate it as it was a papadam.
23. ***Helicteres isora***: Very important forage plant for ungulates as it is abundant. Saw sambar feeding on the leaves in Panna TR. In Gir saw wild pigs using the branches to build the nest.
24. ***Kydia calycina***: Leaves fondly eaten by wild ungulates. Elephants love the bark.
25. ***Lannea coromandelica***: Leaves should be an important fodder for ungulates, fruits too - available only when fallen. In the 1990s when there was serious drought, *Gujjars* in Sariska landscape fed the buffaloes the bark and branches of this tree.
26. ***Lantana camara***: Young leaves are eaten by all animals including dhole and elephants. It is an invasive, exotic and needs to be controlled at Gir.
27. ***Miliusa tomentosa***: Ungulates should be feeding on them in spite of the strong aromatic smell. Regeneration is fair.
28. ***Randia dumetorum***: Leaves are eaten and in spite of that there seems to be good regeneration. Fruits are very important for wild ungulates in late winter and summer. AJTJ Collected 4-5 kills and weighed the fruits in the rumen. Occurrence of fruits was significant (**Ref:** Johnsingh, A.J.T. 1981. Importance of fruits in the fare of chital in the dry season. *J. Bombay Natural History Society 78*:594-595)
29. ***Schleichera oleosa***: Leaves should be eaten by all the ungulates, chital do feed on these. Livestock feed more on this species (Dave 2008). The sap in the fruit is sour and tasty in summer.

30. ***Tectona grandis***: Sambar feed on the bark and leaves –possibly droped by langur. In the forest, didn’t see any feeding signs on the teak leaves. In Bandipur TR, a young sambar stag ate all the *T. grandis* leaves that were dropped by the langur which had eaten only the petiole.

31. ***Terminalia tomentosa* and *T. bellerica***: Both are exceedingly important. Langur are needed in the forest if the ungulates have to feed on the leaves and *T. bellerica* fruits. Regeneration of both is a big worry. Lots of young trees of *T. tomentosa* were seen in Gir East, but no regeneration. Climatic conditions earlier were possibly much more suitable for the growth of the species particularly in the eastern Gir.

32. ***Zizyphus nummularia***: Forage value may be little. Leaves eaten by chital and fruits eaten by wild pigs, jackal and sloth bear (based on observations in Kuno) as well as chital at Gir.

33. ***Z. mauritiana***: Leaves extremely nutritious. Fruits fondly eaten by all ungulates and carnivores like sloth bear, jackal - available throughout winter and fallen fruits till spring (March).

34. **Z. oenoplea**: Young leaves eaten by all ungulates. Fruits too consumed by all animals including birds.

35. ***Z. xylopyrus***: Very important forage plant. Leaves are eaten by all ungulates. Langur also feed on the leaves. Sambar and nilgai eat the fruits. We saw langur up in a *Z. xylopyrus* tree and chital and sambar below feeding on the leaves dropped by the langur.